

VAPOR CONTAINMENT STRUCTURE TESTING UPDATE

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ABSTRACT

The U.S. Army Engineering and Support Center, Huntsville is actively involved in the location and removal of buried unexploded munitions at formerly used defense sites (FUDS). In some cases the munitions are liquid filled which may indicate hazardous chemical agents. A critical parameter for chemical warfare material (CWM) safety siting is the downwind hazard in the event of an accidental detonation. A environmental steel arch vapor containment structure (VCS) over a munition removal site can reduce the downwind hazards resulting from the accidental detonation of CWM. This decrease in downwind hazards allows significant reductions in the required evacuation distance. The initial development of the VCS was in support of the Spring Valley (Washington, D.C.) removal project. A discussion of the Spring Valley development, deployment, and lessons learned will be discussed in this paper including a description of the VCS, structural features of the structure pertaining to blast and chemical agent containment, the model munitions, as well as an overview of the tests conducted and a brief summary of the test results, are presented in this paper. Tests were conducted using replica scale models of the "Livens" and the 4.7-inch munitions, filled with an inert agent simulant and detonated inside of a

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full scale VCS. Additional tests on the VCS are being conducted to enhance the usability of the VCS. A maximum allowable bare explosive charge limit has been established for the VCS and the tests conducted to establish this limit will be covered in this paper. Capture efficiency tests for two to three charge weights will be conducted in fiscal year 1997. This will allow for the use of the VCS for charge weights up to the explosive limit. This paper will also discuss other containment options and uses. These include the development of a partial containment annex to the VCS, which uses open suction hoods near the release point with high suction flow rates to capture a non-explosive release of chemical agent. All efforts are conducted in support of the Huntsville Center's Ordnance and Explosives Army Mandatory Center of Expertise and the Innovative Technologies Program.

1.0 INTRODUCTION AND BACKGROUND

The U.S. Army Corps of Engineers is currently involved in the location and removal of buried unexploded munitions at formerly used defense sites (FUDS). In some cases these munitions will be liquid filled rounds which may contain hazardous chemical agents (CWM). A critical parameter for safety siting is the downwind hazard in the event of an accidental detonation of such a chemical round. The use of a vapor containment structure (VCS), in combination with a high efficiency particulate air (HEPA) filter and activated charcoal air filtration system, over the removal site can substantially reduce the downwind hazard.

1.1 Spring Valley

On 5 January 1993, a civilian contractor uncovered a quantity of World War I munitions while digging a utility ditch for home construction in the Spring Valley community of Washington, D.C. An emergency response by the Army Explosive Ordnance Disposal (EOD) and the Army Technical Escort Unit (TEU) identified the munitions as possible chemical ordnance.

Operation Safe Removal was initiated to remove the ordnance. Phase I was completed by the end of January 1993 with a safe removal of 137 munition items. Phase II Operations were then initiated by the COE, Baltimore District with technical support from the Ordnance and Explosive Waste Mandatory Center of Expertise and Design Center at COE, U.S. Army Engineering and Support Center, Huntsville (HNC). Phase II operations included historical research of the Former Camp American University Experiment Station and Camp Leach, surveying and mapping the area, geophysical surveys of the selected properties, coordinating with the public of all activities, development of planning documents and coordinating logistical requirements for the excavation, storage, and transportation of all recovered munition items. As an element of Phase II, a geophysical survey

was performed utilizing non-intrusive investigation techniques and mapping of geophysical signatures of anomalies of the surveyed properties.

The anomaly discovered at Wesley Seminary on the Former Camp American University area was determined to be possible buried chemical warfare material (CWM). The close proximity with Wesley Seminary and the American University to the anomaly site posed numerous logistical and safety problems. The no significant effect (NOSE) distance predicted for this anomaly was calculated at 329 meters for an un-contained detonation. The standard procedure is to evacuate all nonessential personnel and the public to a distance outside of the NOSE distance when suspected chemical ordnance is unearthed. The NOSE distance calculated would encompass all of Wesley Seminary, a large portion of the American University including student housing, and several residential homes in Spring Valley. This was deemed unacceptable due to its high cost and serious logistical complexity. A method to safely reduce the NOSE distance was required.

HNC was tasked to develop an engineering control solution to reduce the NOSE distance. The concept developed was simple and extremely effective. The concept is to place a vapor containment structure (VCS) over the removal site, maintain a negative pressure differential between the inside environment and the outside, and filter all air inside the structure through an HEPA and activated charcoal air filtration system. This ensures that any static release of chemical agent will be contained and filtered. Unfortunately, the suspected ordnance, the Livens Projector and the 4.7" Mark V artillery, provide a dynamic release of agent. These rounds also pose a fragmentation hazard. A complete containment of agent under these conditions is not assured. In order to determine the effectiveness of the VCS for containment of agent from a detonation of suspect munitions the concept had to be field tested.

In January of 1994, a VCS prototype program was initiated by HNC to determine the containment efficiency of the VCS. The development of the VCS, testing at Southwest Research Institute (SwRI) and its deployment at Spring Valley will be covered in this paper.

1.2 Additional VCS Testing

1.2.1 Maximum Allowable Explosive Bare Charge Limit Testing

In order to enable a more flexible use of the VCS, HNC initiated testing of the VCS by SwRI to determine the VCS's reaction to various bare charge weights and to determine the maximum allowable explosive bare charge limit for the VCS. The testing is complete and the results will be discussed in brief in this paper.

1.2.2 Capture Efficiency Testing

HNC is starting the test program to determine the agent capture efficiency for various charge weights. The testing is expected to be conducted by SwRI on the VCS erected there. A short discussion of the expected test program and desired results is included in this paper.

1.3 Other Containment Options

A brief discussion of other containment techniques and on-site demilitarization of CWM is also included in this paper.

2.0 SPRING VALLEY DEVELOPMENT AND TESTING OF THE VAPOR CONTAINMENT STRUCTURE

The VCS selected for development (Figure 1) was a 14 gage corrugated steel arch manufactured building with a 5000-cfm HEPA and activated charcoal air filtration system. The factors in selection were expected ease of construction, availability, and durability in an explosive loading environment.

Southwest Research Institute (SwRI) in San Antonio, TX was selected in January 1994 to test the VCS to determine its containment efficiency. The VCS prototype was erected on the SwRI facilities in preparation for testing. The VCS was erected on a sand bag base with concrete blocks used to provide structural restraint against the predicted worst case interior loading from a detonation.

The sand bag base was used to evaluate the use of sand bags as leveling tools in the field. Since intrusive activities are discouraged before the actual removal operation, no base leveling with bulldozers or backhoe were expected. Use of sand bags is the expedient way to level the site without digging.

The first task in the evaluation of the VCS is to determine accurate detonation parameters. Analytical models used for conventional explosives do not always accurately predict the loadings for chemical ordnance. In this case both the Livens Projector and 4.7" Mark V had high ratios of chemical agent fill to explosive burster quantity. This tends to damp out the shock loads. If the agent is relatively non-combustible, the agent will quench the fireball eliminating any serious quasi-static pressure increase. Fragmentation analytical models greatly over-predict fragment velocity when dealing with liquid filled munitions. An accurate determination of the detonation parameters is necessary for both the prototype test evaluation and the field use.

2.1 Arena Tests

Arena tests were first performed on the two suspected munitions. These tests had three objectives. First, the munitions equivalent explosive weight in bare TNT must be determined based upon the side-on pressures measured. Second, the fragmentation potential for the munition must be evaluated. Finally, the munitions effectiveness in agent dispersal must be evaluated.

2.1.1 Munition Descriptions

Actual Livens munitions were not available for use in the test program and drawings of the Livens Projector were used to fabricate full scale geometric models of the Livens munition. The model munition was fabricated using two hemispherical endcaps machined to the same thickness of the Livens munition (3/16 inch thick). These endcaps were welded to a cylindrical section having a wall thickness of 3/16" inches. One of the endcaps was designated the fill side of the munition and had a 1 inch hole drilled in the endcap and a threaded coupling welded over the hole to allow for filling the munition with simulant. The other end of the munition had the burster tube welded to it. The steel burster tube had 1.34 inch outer diameter and a 1.0 inch inner diameter. The burster extended 15 inches inside of the munition as shown in Figure 1. The end of the burster tube inside the munition was sealed to prevent the contamination of the burster charge by the chemical agent simulant. The other end of the burster tube extended out of the munition approximately 1 inch and was threaded to accept a cap which was used to seal the burster well after the explosive and detonator were placed inside the burster well. All steel components of the model Livens were constructed of A36 steel.

The Livens had a 0.16 pound TNT equivalent burster. The actual Livens was filled with the liquid form of chemical phosgene at roughly a pressure of 60 psi. The Livens function simply by the burster destroying the outer containing shell and dispersing the phosgene which upon release to atmospheric pressure vaporizes into a cloud.

Actual 4.7" Mark V munitions were also not available for the tests to be conducted. A model munition was fabricated that was simplified in order to reduce cost of fabrication while maintaining the fragmentation, overpressure, and agent dispersal characteristics of the actual munition. The burster and nose configuration of the actual munition is close to that used in the simplified munition with the case thickening at the end of the cone curvature. The majority of fragments would result from this nose section around the burster of the actual munition and the simplified munition. The tail sections of both the actual and

simplified munition will break up into larger pieces with low velocity components.

The 4.7" Mark V artillery has burster explosive weight of .27 pounds of TNT. The 4.7" is also filled with liquid phosgene at 60 psi.

2.1.2 Arena Test Setup

The munition was surrounded by four velocity screen bundles and 14 gauge steel witness plates. The velocity screen bundles were used to capture fragments and predict fragment velocity. The witness plates were used to evaluate the fragment's ability to perforate a 14-gage steel structure at close range. Two PCB pencil type pressure gauges were used to determine the side-on overpressure resulting from the detonation.

The electronic velocity screens were constructed of bundles of celotex faced by two layers of foil separated by a poster board. The foil layers functioned as an open switch in a circuit. When a fragment penetrated the screen and came in contact with both layers of foil, the circuit closes and sends a signal to the data recorder. Electronic break wires were attached to the munition so that upon detonation another signal was sent to the data recorder. With the time zero given by the break wires signals and the impact time given by the velocity screen, an estimation of fragment velocity can be made.

Another method of fragment velocity was used by evaluating the fragments using the THOR equations for depth of penetration into the celotex bundles. Given the fragment mass, presentation area relative to celotex bundle impact, and depth of penetration into the bundles, and estimation of impact velocity can be made. The limitations on this technique are that the fragment tends to roll and may not give an accurate prediction.

Two simulants were used in the arena tests, ethylene glycol and SF6. Ethylene glycol has a specific density approximate to that of liquid phosgene. SF6 has dispersal characteristics to phosgene vapor, is non-combustible, and has low detection limits. Ethylene glycol was used to determine the actual fragmentation attributes of the munition while SF6 was used to determine the effectiveness of the VCS for containment of agent.

2.1.3 Arena Test Results

The major objectives, as previously stated, were to evaluate overpressure, fragmentation, and agent dispersion from a munition detonation.

The pressures which best match the actual pressures expected from a detonation of a Livens Projector are from the model munition

containing ethylene glycol as its agent simulant. This simulant best models the blast performance of the munition since it has a specific density approximate to that of the actual Livens.

The side-on pressure measured by the pencil gauges set at a horizontal distance of 4 feet from the munition was 0.93 psi. Using the computer program CONWEP, an equivalent charge weight in bare TNT for a near surface hemispherical burst is determined. This charge weight is 0.0006 pounds. This is a marked difference from the actual burster weight of 0.16 pounds and demonstrates dramatically the effects of a large liquid agent fill to charge weight ratios.

The applicable overpressures for the 4.7" Mark V result from the arena test of the ethylene glycol filled munition for the same reasons as discussed for the Livens.

The side-on pressure for the 4.7" measured by the pencil gauges set 4 feet from the munition was 4.7 psi. Using the computer program CONWEP, an equivalent charge weight in bare TNT for a near surface hemispherical burst is determined. This charge weight is 0.02 pounds. While the difference between the calculated charge weight and the actual burster weight of 0.27 pounds, there is still a significant reduction resulting from the fill material and casing. The liquid fill to charge weight ratio is less than that of the Livens and correspondingly there is less of a reduction in pressure.

As previously mentioned, the fragmentation of the munitions was evaluated in three ways. First the maximum fragment velocity was determined using the data from the velocity screens. Second the fragment velocity of individual fragments were calculated using the THOR equations based upon the fragment characteristics and depth of penetration. Finally the 14 gauge witness plates were visually inspected for fragment perforation.

The arena tests which best model the actual munitions were the ones using the ethylene glycol filled munitions. The ethylene glycol filled munitions best model the blast response of the munition since the specific weight of ethylene glycol and liquid phosgene are similar.

The model Livens had a large liquid fill to burster weight ratio and the outer shell was comparatively thin. This causes the munition to break up in a manner similar to that of pressure vessel failure. The shell remained largely in two pieces with the shell petalled back around the burster. The fragments which impacted and penetrated the velocity screens were very small and posed no threat to the 14-gage VCS structure.

The model 4.7" munition the liquid fill to charge weight ratio was significantly less than that of the Livens and this results

in a failure mechanism similar to that of conventional ordnance. The shell broke up into two large tail section pieces and numerous long slender fragments from the nose section. There were some fragment perforations in the witness plates. The velocities measured by the velocity screens and calculated using the THOR equations indicated that both the tail section and the nose section fragments could perforate the VCS structure.

The total number of possible model 4.7" munition fragments which could perforate the VCS structure was calculated based upon the test results.

Chemical agent dispersion aspect of the munition detonation was evaluated solely on visual inspection. Both the model Livens and 4.7" Mark V performed up to expectations with good agent dispersal. No liquid remained with either round after detonation.

2.2 Spring Valley VCS Prototype Test

The testing of the VCS was simple in concept and difficult in implementation. The method of evaluation was to cover the VCS structure with a capture tent connected to a high velocity fan (Figure 2). Any simulant escaping the VCS after a detonation of a SF6 munition was captured by the tent and the simulant dosage was measured by a continuous monitor in the annulus connecting the capture tent to the fan. There was also a monitor on the exhaust from the VCS filter system. From measurements recorded by these two monitors the effectiveness of the VCS in percent agent captured was determined.

Numerous Summa type capture devices were placed around the VCS to determine the worst leakage locations. Several devices were also placed outside the capture tent to measure the simulant dosage that was not captured by the test setup. These devices function as vacuum samplers which sample all air around them for 20 minutes. They are then sent to a laboratory to determine the total simulant dosage captured.

Blast gages were placed inside the VCS and two pencil type overpressure gauges were placed outside the VCS in front of the roll-up door.

2.2.1 Results

The VCS was tested for the model Livens munition with SF6 fill first. The munition was detonated in a 3.0 feet deep pit simulating a removal operation. The measured efficiency of the VCS for the Livens was greater than 99.4% agent captured. The shock wave pressures measured were between 1 and 2 psi and the VCS sustained no damage. There was no significant quasi-static pressure increase.

The 4.7" Mark V was also detonated in a 3.0 feet deep pit with shielding used to restrain the fragments. The shields were necessary due to site limitations at SwRI and were constructed so as to not inhibit simulant dispersal. The VCS structure was pre-perforated to account for expected perforation based upon the results of the arena tests. The measured efficiency of the VCS for the 4.7" Mark V was greater than 99.7% agent captured. The shock wave pressures measured were between 2 and 4 psi and the VCS sustained no damage. There was no significant quasi-static pressure increase.

3.0 FIELD DEPLOYMENT AT SPRING VALLEY - WESLEY SEMINARY

The VCS was deployed at Spring Valley's Wesley Seminary site following the completion of testing in September 1994. The site had a rough slope of around 10%. While this would not hinder performance of the VCS it was decided that the public perception of the competency of the VCS could be hampered by the structure being placed upon a slope. It was decided to level the structure using a combination of trenching and sand bags. The structure was erected by a contractor using a telescoping forklift and several laborers. There were 1/8 inch thick blast shields placed over the openings of the air system intake and exhaust. Ramps were provided at each door. The structure was restrained using cables attached to mobile home anchors. It took roughly a week and a half to construct the VCS.

3.1 Benefits From Deployment

The benefits of using the VCS at Wesley Seminary were dramatic. If suspected chemical ordnance were unearthed without protection, the surrounding community must be evacuated to distance greater than 329 meters. This corresponds to an evacuation area of 3,660,000 square feet or 340,000 square meters. The required evacuation distance for the Livens and 4.7" Mark V inside a VCS are 50 meters and 20 meters respectively. This corresponds to an evacuation area reduction of 97% for the Livens and 99% for the 4.7" Mark V. The evacuation area required using the VCS at Wesley Seminary encompassed one home only.

3.2 Field Deployment Problems and Lessons Learned

Several problems occurred during deployment.

The VCS structure was placed in a trench and on sand bags in order make it level. The soil in the trenches was not compacted and the structure tended to settle in the loose fill. This could have been avoided by use of sand bags in the trench on top of compacted soil.

The ramps used posed several problems. The ramp connection had to be flexible in order to account for uneven terrain. The ramps

selected would not allow the roll-up door to be closed and the ramp surface was too slick. The ramps also tended to sink into the wet ground. A standalone ramp unit could be used which has a larger base which would help prevent settling by spreading the load out. Since the ramp is a standalone unit, it will not interfere with door operations. A lugged surface should also be used.

The manufactured structure used as the VCS shell was heavy and awkward to erect. The bolt holes did not align correctly in some cases and the access to some bolt locations was limited. These problems could be mitigated by better coordination with the manufacturer to enhance the constructability of the structure.

4.0 ADDITIONAL VCS TESTING

It is expected that the VCS tested and deployed at Wesley Seminary will be used for other removal projects. In support of these future projects a test program has been initiated to provide a baseline generic assessment of the VCS's explosive resistance and agent capture efficiency. The prototype structure remains at the SwRI research site. HNC is conducting baseline tests for explosive resistance and agent release on the VCS. The baseline tests include two phases.

4.1 Maximum Allowable Explosive Bare Charge Limit Testing

First the maximum allowable explosive bare charge limit must be established. The VCS was tested for several charge weights to determine the structures reaction to explosive loading. Charge weights of .1, .18, .4, .8, 1.0, and 1.2 pounds of C-4 were tested.

4.1.1 Testing

Two preliminary tests of the VCS, with only roll-up door and roof displacement gages installed, were conducted. The tests were conducted to verify the performance of the linear displacements gages or "string pots." Preliminary test 1 was conducted with 0.1 lbs of C-4; preliminary test 2 was conducted with 0.18 lbs of C-4. Both charges were placed in the geometric center of the structure floor, 3 feet off the ground surface. The results of those tests indicated that the gages functioned properly, that the roll-up door was not as stiff as anticipated, and that motion of the entire front wall of the structure was contributing to door displacement measurements. Modified door and backwall calculations, based on measured natural periods of the door and rear wall, suggested that a 2 lb load would be the maximum at which catastrophic failure of the door and rear wall would occur, providing no other failure modes (such as the personnel door) occurred first.

In loads test 1, 0.4 lb of C-4 was placed in the structure. Results indicated minimal to negligible damage to the structure. In loads test 2, 0.8 lb of C-4 was detonated. Again, minimal to negligible damage was observed. The only damage to be noted was a slight deformation of the corrugated panels at the structure base where they are bolted to the floor beam. The floor beam spanning the rear wall also exhibited some indications of slight (0.5 in.) outward "bowing".

Loads test 3 was performed with 1.0 lb of C-4. The results of this test indicated that the rear personnel door frame was beginning to fail, and that the roll-up door bottom stiffener was beginning to plastically deform slightly (0.5 in.). The personnel door frame had broken welds, was displaced outward at least 1 in. at the top left corner when observed from the outside, and the door was deformed about the same amount. Both doors were still operable. Loads test 4 was conducted with 1.2 lbs of C-4. In this test the roll-up door stiffener (Figure 4) was further displaced to about 1.5 in. The personnel door frame (Figure 3) was pushed out an additional 2 in., and corrugated cladding above the frame was pulled loose from the structure at one location. The rear wall was apparently not damaged otherwise. The front wall was noticeably deflected outward in a three panel configuration, where the panels to the side of the roll-up door and the panel above the door were displaced at the door frame about 2 in.

After discussions between SwRI and HNC, testing was stopped due to damage to the roll-up door. The maximum allowable explosive bare charge weight was set at 1.2 pounds C-4. Repairs required after the loads test 4 consisted of removal, rebuilding and replacement of the personnel door and frame as a "stiffened cantilever" off the floor beam and repairs to the roll-up door and frame.

4.2 Capture Efficiency Tests

Following the loads tests, Phase II will be conducted to determine the agent capture efficiency for the VCS for various charge weights. The testing will be similar to the prototype VCS efficiency test. The capture efficiency will be established for three charge weights ranging up to the maximum allowable charge. Two tests will be conducted for each charge weight to ensure better reflect expected efficiencies. Capture efficiency testing is planned to be conducted at SwRI in fiscal 1997.

Once the baseline tests are complete, the VCS can be used for any chemical munition with a charge weight less than the VCS explosive charge limit and if it meets the fragmentation limitation. The withdrawal distance will be calculated based upon

the VCS capture efficiency at chemical munitions charge weight and the actual amount and type of agent fill.

4.3 VCS Use Parameters

The VCS can be used after baseline testing is completed for other CWM removal projects. The following issues must be resolved before deployment at the site:

Is the net equivalent charge weight of the CWM item less than 1.2 pounds C-4?

Will fragmentation cause serious damage to the VCS?

What is the capture efficiency for the VCS for the expected CWM item?

Is the resulting NOSE distance acceptable and does the VCS use provide greater benefits than costs for site at which it is to be used?

The VCS cannot be used if the blast pressures are above those for 1.2 pounds C-4 or if heavy fragmentation is expected. The NOSE distance for the particular deployment must be determined based upon the capture efficiency. The NOSE can be calculated using a computer program called D2PC.

5.0 OTHER CONTAINMENT OPTIONS

5.1 Vapor Containment Fabric Structure

Other vapor containment structures and devices which could be used in nonexplosive environments for capture of static releases are being used and developed. Light weight vapor containment fabric structures (VCFS) have been used for containment of static releases and future operations using these lighter structures are planned (Figure 5). Future testing of these lighter structures is anticipated. Issues to be tested include resistance to blast pressures, fragment resistance, tear resistance, and agent capture efficiency.

5.2 Partial Capture System

Another CWM agent capture system is the partial capture system (PCS). The PCS is an engineering control that was developed by HNC to capture the majority of a static (nonexplosive) release of agent inside a pit or trench. The PCS uses two suction heads along side a trench or pit connected to a high-flow fan system which will generate a 35,000 cfm suction air flow rate. The PCS is shown in Figures 6,7,8 and 9. If wind screens are provided the PCS can capture close to 100% of an agent release. An air filtration system must be attached to the high-flow fan outlet.

This air filtration system must have the same flow capacity (35,000 cfm) as the fans. Additional refinements to the PCS are anticipated including enlarging the shroud, testing lower flow rates, and small quantity explosive release tests.

5.3 Emergency On-Site CWM Demolition

Another use of the VCS is also be considered and analyzed.

HNC developed an on-site ordnance demolition container for use in cases in which an open or buried detonation of ordnance is not allowed. The container has been tested and validated for repetitive use for detonations of up to six (6) pounds TNT and fragmentation of 57mm artillery shells or equivalent. The container system is designed to prevent all fragments, and the majority of the blast pressures from escaping the container. An interior blast mat is used to capture the majority of fragments, preventing damage to the outer shell. The outer shell can stop all fragments from a detonation without benefit of the blast mat. The overpressures are mitigated using water bags placed around the munition prior to detonation.

HNC is analyzing the possibility of using the on-site ordnance demolition container with the VCS to provide an emergency on-site demolition process for recovered CWM (Figure 10). Initially, HNC is looking at demolition of non-explosive CWM such as chemical agent identification kits. Methods being considered include using a caustic solution in lieu of water in the water bags and/or using a 5 to 1 ratio of explosive to agent. The caustic solution may neutralize the agent, and the 5 to 1 explosive to agent ratio has been shown to combust a majority of a phosgene release in previous testing. Further analysis is ongoing and future testing is anticipated.

8.0 CONCLUSIONS

The U.S. Army Engineering and Support Center, Huntsville, Ordnance and Explosive Waste Mandatory Center of Expertise and Design Center is dedicated to developing better and more efficient ways of containing and mitigating the effects of accidental releases of harmful chemical agents. HNC strives to use the latest technologies with available materials and tools in order to better protect the environment and the public at lower ordnance removal costs through its Innovative Technologies Program.

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3. Marchand K.A., Bowles T., May 1996, "SwRI Project 06-7996, Loads Tests for the HNC Steel Arch VCS Monthly Progress Report," Southwest Research Institute



Figure 1 - VCS (Spring Valley)

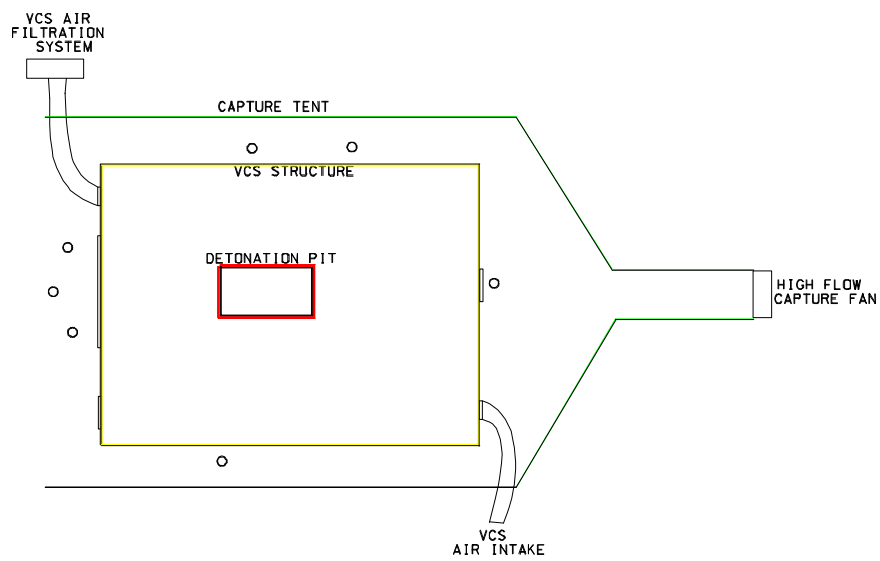


Figure 2 - Vapor Capture Test Set-up



Figure 3 - Personnel Door Damage



Figure 4 - Roll-up Door Damage

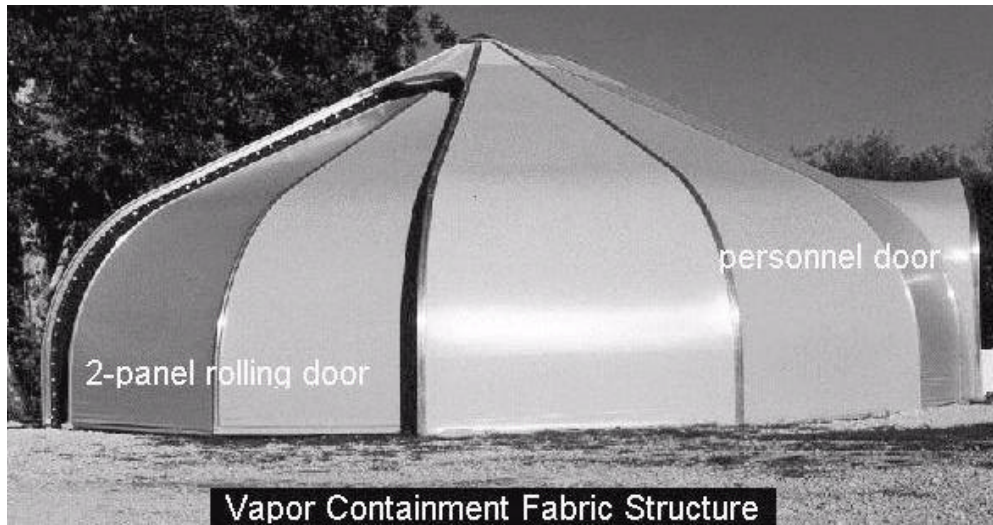


Figure 5 - Fabric VCS



Figure 6 - PCS (Shroud Up)



Figure 7 - PCS (Shroud Down)

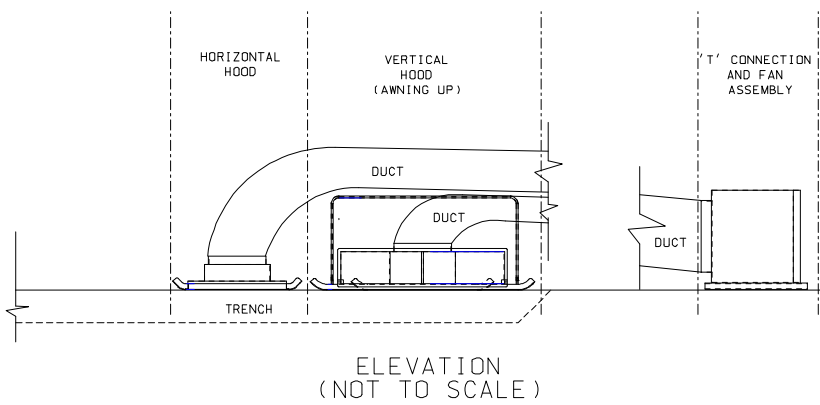


Figure 8 - PCS Set-up (Elevation)

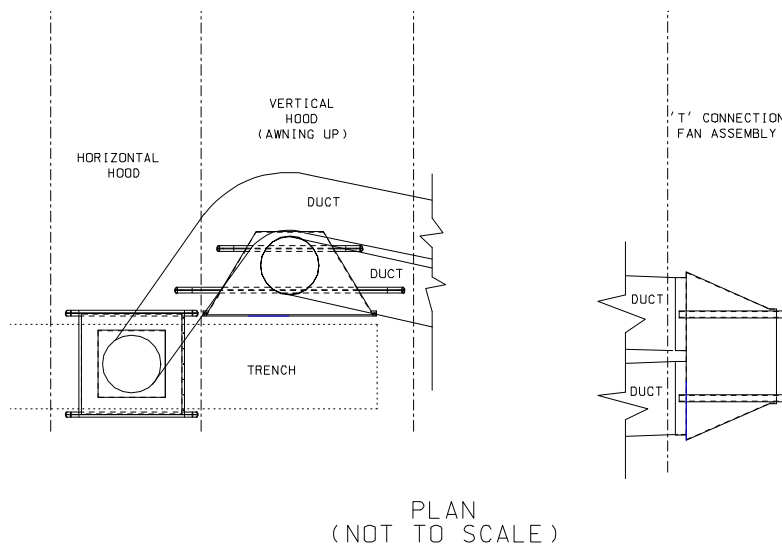


Figure 9 - PCS Set-up (Plan)

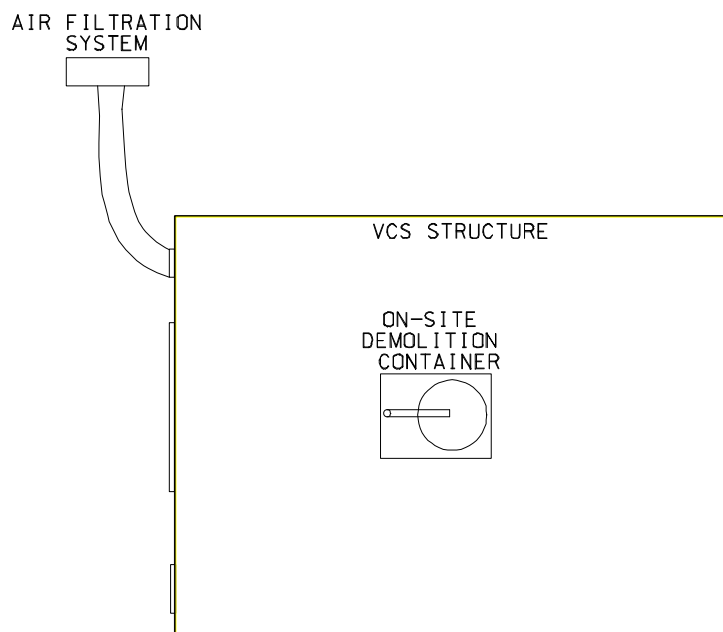


Figure 10 - Emergency On-site CWM Demolition Set-up